APPLICABILITY OF THE UNIVERSAL SOIL LOSS EQUATION FOR SOUTHEASTERN IDAHO WILDLANDS[1]

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Abstract.— In 1981, 20 sediment-collecting tanks and troughs were installed on range and timbered sites of the Caribou National Forest. Measured erosion losses from the first year of study were contrasted to Universal Soil Loss Equation (USLE) estimates utilizing three different vegetative factors. State of Idaho C factors, National Rangeland C factors, and the Vegetative Management (VM) factors were studied. The erosion estimates of all three USLE tests were significantly different than measured soil losses. All equations overestimated the measured mean soil loss, 0.52 megagrams/ha/yr (0.23 tons/ac/yr), by 33, 3,000, and 2,000 percent, respectively. The soil erodibility factor (K), Rangeland C, and VM showed significant relationships to soil loss. The K and VM factors accounted for 88 percent of the variability in sediment loss in multiple regression models. Erosion equations suitable for use on this study area are presented.

Soil scientists are frequently required to provide land managers with estimates of soil erosion rates on specific sites. The ongoing preparation of Land Use Plans for forests managed by the U.S. Forest Service, Intermountain Region, has increased the need for realistic approaches to estimating erosion rates. The Universal Soil Loss Equation (USLE) is the dominant method used in making soil erosion estimates within the region (Wischmeier 1968). However, questions have been raised as to the validity of this equation when applied to wildlands (U.S. Department of Agriculture 1982). The USLE was developed for agricultural lands where overland flow and erosion processes comparable to those described by Horton (1933) are operable. Such erosion processes are usually not encountered on wildlands with good vegetative cover and snowmelt runoff. Accordingly, it seems likely that the USLE parameters will require modification for use on wildlands to insure that they will give reasonable erosion estimates. A description of the USLE factors used in this study is presented in Table 1. The primary objective of this study was to contrast the actual surface erosion rates of some southeastern Idaho wildlands to estimates derived by the USLE. A further objective was to determine which of the USLE parameters showed the strongest relationships to measured soil loss. Such information will improve the usefulness of the USLE on wildlands.

Study Area

The Caribou National Forest is in southeastern Idaho, covering an elevational range of 1,490 to 2,930 m. (Fig. 1). The forest lies primarily within the Middle Rocky Mountain physiographic province, with some inclusion of the Basin Range physiographic province (Fenneman 1931). The geology is rather complex, ranging from Precambrian metamorphics in the Bannock and Portneuf Ranges,

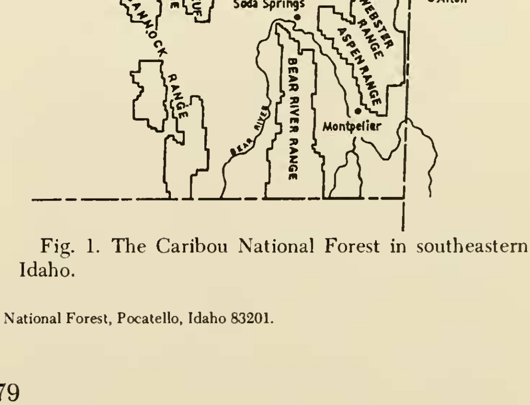

Fig. 1. The Caribou National Forest in southeastern Idaho.

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TABLE 1. A description of the Universal Soil Loss Equation factors used in this study.

The Universal Soil Loss Equation Model is

$$A = Rt\,K\,L\,S\,C\,P$$

Where:

- A = The estimated average soil loss per unit area in tons/acre for the time period selected for Rt, usually 1 year.
- Rt = The rainfall factor, usually expressed in units of the rainfall-erosivity index, EI, and evaluated from an iso-erodent map.
- K = The soil-erodibility factor, usually expressed in tons/acre/EI units for a specific soil in cultivated continuous fallow tilled up and down slope. Values for K in this study were determined from the soil erodibility nomograph.
- L = The slope length factor, the ratio of soil loss from the field slope length to that from a 22.1 m length on the same soil, gradient, cover, and management.
- S = The slope gradient factor, the ratio of soil loss from a given field gradient to that from a 9 percent slope with the same soil, cover, and management. In this study, the L and S factors were computed together, using the topographic factor (LS) nomograph.
- C = The vegetative factor, the ratio of soil loss from land managed under specified conditions to that from the fallow condition on which the factor K is evaluated. Three methods for determining this factor were studied. They are: (1) State C factors that are determined by the Rt values for a site; (2) National Rangeland C factors determined by the canopy cover, vegetation type, and ground cover on a site, and (3) Vegetative Management factors determined by the canopy cover, ground cover, and percent of bare ground with fine roots on a site.
- P = The erosion control factor, not usually applied to wildlands.

NOTES (a) These factors take on dimensionless values when computing A.
(b) Source = Warrington, 1980.

Jurassic-Triassic sedimentaries in the Bear River and Webster Ranges, to Cretaceous sedimentaries in the Caribou Range.

Bailey (1980) has classified the vegetation of the forest as belonging to the Rocky Mountain Forest Province—Douglas Fir Forest section and the Intermountain Sagebrush Province—Sagebrush-Wheatgrass section. The climate is a semiarid steppe regime with a wide range in mean annual precipitation. The lower elevations receive 330 mm of precipitation per year, and higher elevations commonly experience 1,524 mm annual precipitation. Approximately 60 percent of the precipitation is in the form of snow. Most soil erosion is observed to occur during the spring snowmelt period.

METHODS

In the summer of 1981, 20 erosion plots were installed on the Caribou National Forest. Plots were equipped with erosion tanks and troughs to catch surface erosion losses induced by soil creep and sheet erosion. The data presented is from the 1981–1982 erosion year. The erosion plot construction techniques used were comparable to those employed in Montana by Packer and Williams (1976). Erosion plots were .015 hectare in size, with dimensions of 2.4 by 10.1 m. The long axis of each plot was oriented up and down slope. Plots were constructed from 2.5 by 15.2 cm cedar boards on the top and sides. A metal trough, 15.2 cm deep by 25.4 cm wide, was placed on the downhill side to catch sediment. Water and sediment collected from the plots were stored in sealed 907 liter tanks. Tanks were connected to the troughs by 15.2 cm diameter, steel reinforced hose. Sediment was removed from the troughs in early summer after the spring snowmelt. Minimal soil erosion occurred during the summer months. The accumulated sediment was oven dried to determine erosion loss weights.

The USLE factors were computed using the procedures outlined in the WRENS doctrine (Warrington 1980). Rainfall factor values (Rt) were taken from an iso-erodent map developed for Idaho by the Soil Conservation Service (1977). This factor is a water drop impact indicator, with only a small component for runoff. The dominant erosion agent operable on the study sites, however, is snowmelt runoff. Adequate factors for this erosion parameter have not been developed, which necessitated the use of the Rt factor in this study. Length and percent slope at each site were used to determine the LS factors. Soil profile descriptions and lab analyses of the A horizon were made for each site. Soil organic matter was determined by the Walkley-Black Method, and particle size analysis was determined by the Hydrometer Method (Black 1965). Soil erodibility factors (K) were determined by the soil erodibility nomograph

(Warrington 1980). Soil classification followed procedures outlined in *Soil Taxonomy* (Soil Conservation Service 1975).

The cropping management factor (C) is important in estimating erosion on wildlands (Dissmeyer 1980). Three different methods for determining the vegetative factor were tested in this study. They are: (1) the Vegetative Management factor—VM (Warrington 1980), (2) the National C factor for rangelands—Range C (USDA 1977), and (3) state-developed C factors for Idaho—State C (Soil Conservation Service 1977). The vegetative information collected to compute these factors utilized the Range Site Analysis procedures of the Forest Service, Intermountain Region (U.S. Department of Agriculture 1969). The statistical methods employed followed Zar (1974). Sites were selected to sample over a wide range in vegetative and soil conditions.

Results

Site descriptions for the erosion plots are presented in Table 2. Soils of the order Mollisols and sage-grass vegetative types (i.e., *Artemisia vaseyana–Agropyron spicatum, A. vaseyana–Stipa comata*, and *A. vaseyana–Symphoricarpos oreophilus–Agropyron spicatum* habitat types) were dominant (Hironaka 1981).

Table 2. Site descriptions of the erosion plots.

Site number	Soil classification	Vegetative type	Elevation (m)	Aspect	Percent slope
1	Loamy skeletal, mixed family of the Typic Cryoborolls	Sage-Grass	2,620	W	15
2	Fine loamy, mixed family of the Argic Cryoborolls	Mountainbrush	1,950	E	50
3	Fine loamy, mixed family of the Argic Cryoborolls	Sage-Grass	1,980	W	60
4	Loamy skeletal, mixed family of the Argic Cryoborolls	Sage-Grass	1,950	S	60
5	Fine loamy, mixed family of the Cryic Pachic Paleborolls	Sage-Grass	1,830	NW	30
6	Fine loamy, mixed family of the Argic Cryoborolls	Sage-Grass	1,800	NW	21
7	Loamy skeletal, mixed family of the Argic Cryoborolls	Sage-Grass	2,620	S	35
8	Loamy skeletal, mixed, mesic family of the Typic Argixerolls	Sage-Grass	1,830	W	25
9	Fine loamy, mixed family of the Argic Pachic Cryoborolls	Aspen	2,100	E	20
10	Fine loamy, mixed, mesic family of the Typic Argixerolls	Sage-Grass	1,650	W	45
11	Coarse loamy, mixed, mesic family of the Typic Xerorthents	Juniper-Forb	1,610	S	23
12	Fine loamy, mixed family of the Argic Cryoborolls	Sage-Grass	2,130	SE	40
13	Loamy skeletal, mixed family of the Typic Cryoborolls	Mountainbrush	2,070	S	50
14	Loamy skeletal, mixed family of the Typic Cryorthents	Fir-Pinegrass	2,350	W	30
15	Fine loamy, mixed family of the Typic Cryorthents	Fir-Pinegrass	2,200	N	35
16	Loamy skeletal, mixed family of the Argic Cryoborolls	Sage-Grass	1,950	SE	56
17	Fine loamy, mixed family of the Typic Cryoboralfs	Sage-Grass	2,130	SE	42
18	Loamy skeletal, mixed family of the Argic Cryoborolls	Sage-Grass	1,650	SW	60
19	Fine loamy, mixed family of the Mollic Cryoboralfs	Pine-Pinegrass	2,040	N	35
20	Fine, mixed family of the Argic Cryoborolls	Sage-Grass	1,950	S	30

TABLE 3. The Universal Soil Equation predictions for the study plots*.

C Factor used	Mean	Standard deviation	Minimum	Maximum	n
State C	0.72 (0.32)	0.54 (0.24)	0.02 (0.01)	1.86 (0.83)	20
Range C	16.02 (7.15)	35.39 (15.8)	0.76 (0.34)	153.6 (68.6)	20
VM	11.51 (5.14)	31.81 (14.2)	0.20 (0.09)	138.4 (61.8)	20
Measured rate	0.52 (0.23)	1.37 (0.61)	0.02 (0.01)	5.8 (2.6)	20

*The first number provided is in units of megagrams/ha/yr. The second number provided is in units of tons/ac/yr.

NOTE: The erosion predictions derived by all three C factor methods were found to be significantly different than the measured erosion losses by use of a Wilcoxon Paired Sample Test at the 95 percent confidence level.

The USLE was tested for each site using the three vegetative factors (Table 3). Erosion loss estimates from all three USLE tests were significantly different from measured losses as determined by the Wilcoxon paired sample test. The USLE that utilized the State C factor provided the most reasonable estimates; it overestimated the mean erosion loss of the sites by 33 percent. USLE predictions that utilized the VM and Range C factors overestimated the mean loss by 2,135 and 3,010 percent, respectively. These factors also yielded high standard deviations for mean losses and large ranges in predicted erosion rates.

To determine how an improvement in the accuracy of the USLE might be made, simple linear regression analysis was performed on the data (Table 4). The percent variability in measured soil loss explained by the USLE factors were 80 percent for VM, 51 percent for Range C, 27 percent for K, 12 percent for LS, and 0 for Rt. The K, VM, and Range C factors showed significant linear relationships to the measured soil loss on the erosion plots. Of the site factors studied, percent canopy cover and percent vegetation plus litter gave significant negative correlation to soil loss. Percent pavement (i.e., rocks less than 1.9 cm in diameter) had a positive correlation to soil loss. Production, percent bare ground, and percent rock on the sites did not show significant linear relationships to measured soil loss.

Table 5 shows Pearson Correlation Coefficients for two soil variables and the USLE factors. Percent clay has a strong positive correlation to soil loss (A) and soil erodibility (K). The organic matter content in the soil showed a strong negative correlation to these factors. Since certain factors of the USLE were not found to have significant relationships to soil loss, equations using correlated variables were developed (Table 6). Stepwise multiple regression analyses indicate that 80 percent of the variability in soil erosion loss is attributable to the VM factor of a site. Considering the K factor with VM accounts for 88 percent of the variability in soil erosion loss. Adding the Rt and LS factors does little toward improving predictions. This relationship is important since the VM

TABLE 4. Linear regression relationships between soil loss (A) and the USLE and site variables.

	Line equation	r^2
USLE variables		
Rt	A = 0.01 + 0.0033 Rt	0.002
K	A* = – 0.48 + 4.12 K	0. 27
LS	A = – 0.19 + 0.05 LS	0. 12
State C	A = 0.37 + 18.85 S-C	0. 02
Range C	A* = – 0.21 + 4.02 R-C	0. 51
VM	A* = – 0.19 + 6.38 VM	0. 80
Site variables		
% Canopy cover	A* = 0.67 – 0.0096 C	0. 17
% Vegetation & litter	A* = 0.83 – 0.0105 VL	0. 23
% Bare ground	A = – 0.06 + 0.0114 BG	0. 09
% Pavement	A* = 0.04 + 0.0146 P	0. 17
% Rock	A = 0.06 + 0.0351 R	0. 08
Production	A = 0.58 – 0.00018 Prod.(kg/ha/yr)	0. 12

NOTES: (1) * Slopes of these equations found to be significantly different than 0 by use of a T test at the 95% confidence level.
(2) Sample size = 20 in all cases.
(3) A is in units of tons/ac/yr. The product A may be multiplied by 2.24 to obtain units of megagrams/ha/yr.

TABLE 5. Pearson correlation coefficients between the USLE factors and soil clay content and organic matter.

USLE factor	% Clay in the A horizon	% Organic matter in the A horizon
Rt	0.15	0.03
K	0.65	–0.57
LS	0.39	–0.32
State C	–0.45	0.14
Range C	0.74	–0.66
VM	0.88	–0.73
Soil loss (A)	0.88	–0.70

Sample size = 20 in all cases.

and K factors can be easily determined through soil profile description and relatively simple vegetative analyses. The Rt factor is variable over wildlands of the Intermountain Region and will probably never be quantified for snowmelt situations. The LS factor also presents a problem for field determinations. An absence of uniformity and the benchy nature of slopes within the region make it difficult to determine a site's contributing slope length and steepness. An accurate assessment of these variables is needed to derive the LS factor.

Actual values for soil loss from plots were used to test the accuracy of different USLE formulations (Table 7). USLE estimates that utilized the State C factor showed a poor correlation with measured soil loss. However, USLE estimates that used the VM and Range C factors showed a high correlation with measured losses; yet they overestimated actual rates. The new equations derived in this paper can be used to scale down USLE estimates when the designated vegetative factors are used to predict erosion on western wildlands.

Discussion

Erosion estimates generated by the USLE were not representative of actual soil losses on erosion plots. The three equations tested significantly overestimated erosion as shown by actual field measurements. This is consistent with the findings of Patric (1982) in his review of erosion research on forested lands. Patric suggests that the USLE tended to overestimate erosion losses on forested sites if limitations of the equation on such lands are not considered. Patric also points out that sediment yields of no more than 0.56 megagrams per ha per year provide an index of soil loss from relatively undisturbed forest watersheds. The mean erosion loss on plots considered in this study (i.e., 0.52 megagrams per ha per year) suggests that erosion rates on the Caribou National Forest are comparable to those on other wildlands.

The Rt and LS factors present problems when using the USLE to estimate soil losses. These factors showed no significant relationship to measured soil losses in this study. This suggests that Rt and LS factors contribute little when the USLE is applied to western wildlands. More information is needed concerning the relationships these factors have to determining soil erosion losses on wildlands with snowmelt runoff.

The K factor showed a significant linear relationship to measured soil losses in this study. Laflen (1982) raised questions about the quality of the estimate that the K factor provides for use on wildlands, because the soils of such areas differ from agricultural soils. Steep slopes, high rock fragment content, and high organic matter content of wildland soils contributed to differences in soil erodibility not addressed by Wischmeir (1969) in his early efforts to develop the K factor concept. The correlation between soil loss and the K factor can be improved with a thorough understanding of soil variables. Percent clay and organic matter in the A horizon were correlated with soil losses and most of the USLE factors considered in this study. Future applications of the USLE to intermountain wildlands should address these soil factors.

USLE predictions, using the three different vegetative factors, gave erosion estimates higher than observed rates. Equations presented in Table 7 offer a means of reducing estimates to more reasonable levels. Equations that utilize the VM and the K factors (Table 6) provide the land manager with a

TABLE 6. Stepwise multiple regression relationships between soil erosion loss (A) and the VM and K factors.

$$A\ (\text{tons/ac/yr}) = -0.19 + 6.4 \times \text{VM factor};\quad r^2 = 0.80,\ \text{standard error} = 0.28,\ n = 20$$

$$A\ (\text{tons/ac/yr}) = -0.55 + 5.8 \times \text{VM factor} + 2.4 \times \text{K factor};\quad r^2 = 0.88,\ \text{standard error} = 0.23,\ n = 20$$

NOTE: (1) The inclusion of the Rt and LS factor increase the r^2 value to 0.89.
(2) The product A may be multiplied by 2.24 to obtain units of megagrams/ha/yr.

TABLE 7. Regression equations correlating USLE estimates with measured soil losses when three different vegetative factors are used.

Vegetative factor used	Correction equation
State C	$y = 0.02 + 0.62x$; $r^2 = 0.06$, $n = 20$
Range C	$y = -0.05 + 0.04x$; $r^2 = 0.97$, $n = 20$
VM	$y = 0.002 + 0.04x$; $r^2 = 0.99$, $n = 20$

NOTE: (1) y = measured soil loss (tons/ac/yr).
(2) x = USLE estimated soil loss (tons/ac/yr).

simple approach for predicting erosion loss. These equations are effective because the two USLE factors that showed the greatest sensitivity in predicting soil loss are used in the construction.

Conclusions

The information collected during the first year of this study will assist those who use the USLE for predicting soil erosion on wildlands. The results presented will be refined as the study continues. Further research is needed to quantify the relationships between USLE factors and soil erosion on wildlands in the Intermountain Region. Specifically, more work should be directed toward developing Rt factors for snowmelt runoff situations. The VM factor offers an effective means for predicting soil erosion. It is particularly useful to the land manager since it allows for the testing of different management objectives against their effects on soil loss.

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